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Protecting the Environment and the Poor

A Public Goods Framework Applied to Indonesia

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Strategies to control air pollution would be altered by redistribution objectives. In an urban program, the emphasis in the control strategy would shift toward services and goods consumed by the rich, including transport. In a program including rural areas, optimal air pollution control would be reduced because many rural households would be net losers, and they are poorer.

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Summary findings

As is evident from public finance principles, redistribution objectives do not influence environmental policies if there are other, costless means of redistribution. How does optimal environmental protection depend on redistribution objectives?

Eskeland and Kong develop a framework that treats air quality as a pure public good, and tracks net beneficiaries as those who value air quality improvements more than their costs in a pollution control strategy.

The framework highlights the distributional characteristics of the public good and of the costs for the control strategy. One critical parameter for the distributional characteristics of the public good is the elasticity (with respect to income) of willingness to pay for environmental improvements.

Strategies to control urban air pollution would be altered by redistribution objectives — to be more aggressive in reducing emissions from luxury goods such as transport (private and general) and less aggressive for goods more heavily consumed by the poor (including several energy sources).

Some air pollution control strategies cover urban *and* rural areas. For those, optimal pollution control would typically be reduced by redistribution objectives, as rural households are net losers, and they are poorer.

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1. Introduction and Background

How does optimal environmental protection depend on income levels, and on concerns for redistribution? In developing countries, natural assets such as trees and soil provide employment and a livelihood to many poor, so it is quite intuitive that protection of such resources can be important even at low-income levels. However, even for problems associated with industrialization and urbanization, such as ambient air pollution, evidence is mounting that control initiatives may be worthwhile. The present study focuses on how strategies to reduce local air pollution in Indonesia affects different income groups, and on how those strategies would be influenced by a particular concern for the poor. The study thus does not ask whether income growth is good or bad for the environment, and does not treat transnational or global environmental problems.[1]

In this introductory section, we briefly visit *Java*, the setting chosen for our empirical investigation. We then present the traditional welfare economic approach to environmental protection, and the simplifying assumptions involved when one excludes analysis of how effects are distributed. We then review some applied studies that have included distributional implications, first in general public finance and then for environmental policies. Section 2 develops an analytical framework and introduces the concept of distributional characteristics for public goods. Section 3 analyzes how distributional considerations would influence air pollution control strategies—first in the balance between alternative control strategies, and then to determine whether optimally provided air quality would be higher or lower under redistributive objectives. Section 4 concludes.

Jakarta and Java—The Setting for the Empirical Analysis

About half of Indonesia's population live on the island of Java (100 million). The soils are fertile, and rural population densities are among the highest in the world. The city of Jakarta is home to about 8 million people, with about twice as many in the greater metropolitan area.

Ambient air pollution levels in Jakarta regularly exceed World Health Organization (WHO) guidelines by factors of two to four. Present analysis indicates that suspended particulates (a measure of dust) should be of greatest concern, due to effects on respiratory diseases and premature mortality. A recent study concluded that significant improvements in public health could be obtained through ambient air improvement.[2]

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[1] On these questions, see, for instance, World Commission on Environment and Development (1987), Mink (1993), Grossman and Krueger (1995), World Bank (1992), and Cline (1992). There are two views on whether pollution control is worthwhile: (i) that few complete cost benefit analyses have been made for a developing country city, and (ii) that actual pollution control reflects that they have been found worthwhile. Examples of benefit estimates for air quality improvements in developing countries are found for Taiwan in Alberini et al. (1997), and for Chile in World Bank (1994), Eskeland (1997), and Bowland et al. (1998). World Bank (1994) and Eskeland (1997) find that modestly estimated health benefits alone would exceed control costs for Santiago, Chile.

[2] Public health improvements include reduced damage to the learning abilities of children, reduced illness among children and adults, and about 1500 fewer premature deaths annually (Ostro 1994).

Our Approach: Public Goods Provision under Redistributive Objectives, and the Polluter Pays

We think of ambient air quality as a pure public good in the sense that it can be consumed (or enjoyed) by one person without excluding the enjoyment of another. Individuals may have a weak or a strong preference for the air quality they collectively enjoy, and their willingness-to-pay to pay for improved air quality may depend inter alia on income and air quality. Emitting pollution into the air, in contrast, is an exclusive activity, and emissions correspond directly to the activity of providing a public good in traditional terminology—though with the opposite sign.

Air pollution is linked to emissions from natural sources, and from human activities such as household energy use, industrial processes and transportation. In terms of physical actions, emission control strategies can (i) reduce the scale of polluting activities; (ii) modify them to pollute less per unit of output, and/or; (iii) move them geographically to less sensitive areas. In terms of policy instruments, such changes are typically stimulated by regulation or market-based incentives, such as emission taxes. Thus, in physical terms air quality is a privately provided public good, but the government serves in a coordinating role, in effect procuring the public good.

The typical prescription from welfare economics is that public goods provision, or pollution control in our case, be pursued to the point where marginal benefits, when aggregated over individuals, no longer exceed marginal cost. It is straightforward to support such advice to an economic planner if she has available instruments that can costlessly transfer income between households (such as lump-sum taxes). In such a case, the government may pursue projects, public goods provision, and environmental policies with sole focus on total costs and benefits, irrespective how these are distributed between households.

Thus limiting the analysis to aggregate net benefits is often described as using "the compensation criterion," since hypothetical compensation of losers is used to link a simple sum of individual experiences with social welfare. Such an analytical basis is typically not very suitable for environmental policies: Efficiency is easier to achieve when polluters face the full cost of their emissions, making compensating transfers either unrealistic or inadvisable (see OECD 1975; Baumol and Oates 1988; Eskeland and Jimenez 1992).

If one excludes costless compensating transfers, increased (or reduced) pollution control would rarely be Pareto-improving, even if aggregate marginal benefits were to exceed control costs by a wide margin. Then, distributional implications can be relevant to policy, and we proceed to analyze the distributional implications for costs and benefits.

Many authors have studied optimal supply of public goods under distortionary revenue generation. Pigou's conjecture was that optimal supply of public goods is lower when transfers to the government are costly than in the case with costless transfers to the government.[3] Since we study a public good that is privately provided (by those who reduce pollution), our emphasis is on redistribution between households, rather than on transfers to government. Still, if lump-sum taxes are available, they eliminate the need to let redistributive objectives influence other policy instruments in our model, just as they do in a model focusing on revenue generation. Our modeling approach for the benefits of public goods provision is very similar to one given in Atkinson and Stiglitz (1980, page 496, citing an unpublished manuscript by Arnott 1978), with a result depending

[3] Stiglitz and Dasgupta (1971), Atkinson and Stern (1974) and others, have examined this question.

on the covariance between willingness-to-pay for the public good and the social marginal utility of income.

In this paper, we develop a model for the evaluation of distributional implications both for the costs of provision and for the benefits, and take it through an empirical application. We identify strategies to reduce air pollution on Java or in Jakarta, emphasizing particulates. We assume that emission reductions are induced directly by regulation, although the analysis can be modified to allow for other instruments, such as taxes levied on emissions or on consumption (all these have in common that they increase the costs to users of polluting goods and inputs). Importantly, if we assumed that the social planner were equipped not only with regulatory instruments (emission standards, say) but also with sector-specific taxes on emissions and outputs, then she would have a richer set of instruments with which to pursue goals. In that case, it would less likely be important to let redistributive objectives goals influence the pollution control program itself (for analysis along these lines, see Eskeland 1996).[4]

Strategies to reduce emissions from households, such as emission standards for household energy use or personal vehicles, will increase the cost of such consumption, and incidence analysis is simple. Incidence analysis for control strategies affecting the economy as a whole (including industries) requires a more involved analysis. Assuming that an industry's increased costs will be passed on to other industries, such control strategies will also result in a pattern of cost increases for consumers. We use input-output analysis to estimate the resulting cost increases of various consumption goods, in order to assess the distribution of costs amongst households.

The benefits of a pollution control strategy, in contrast, will accrue to households living in areas where the air quality improves. Thus, if you live in an area where transport is an important contributor to pollution, and you are not a user of transport services, you will likely be a net beneficiary from a transport control strategy. Apart from the distribution among households of physical environmental improvements, however, the benefit distribution depends on how the households value these improvements. Lacking empirical results on how valuation of air quality varies with income, we employ sensitivity analysis.

To analyze policy changes in a context with winners and losers we employ a welfare function; we may think of it as a planner's tool. It is defined over each household's well-being, and describes how (according to the planner's objectives) one household's loss can substitute for another household's gain[5]. As a starting point, we employ equal priority weight to increments in

[4] The emission reductions resulting from emission taxes can under certain assumptions be replicated by a combination of emission standards and taxes on polluting goods. Thus, the additional (redundant) instruments can be used for redistributive purposes, keeping the emission reductions constant. For instance, one could institute first-best emission controls on cars without harming car-owning households, by combining emission standards with car (or gasoline) subsidies.

[5] A plausible set of welfare functions includes functions that are non-negative in every individual's well-being. A welfare function is concave and redistributive (as is ours) if it applies welfare weights that are non-increasing in individual well-being. Among concave redistributive ones, as extreme cases, there is the Rawlsian welfare function, which accepts a policy change as an improvement in social welfare only if it improves the well-being for the individual that is worst off, and a linear welfare function, which is not strictly concave. Poverty measures can also be interpreted as a set of welfare functions, most of which have in common that they apply a zero weight to welfare improvements beyond a specified threshold level (the poverty line). A frequently used poverty measure,

utility (or well-being) to rich and poor. This selects the *efficient* pollution control program, the one that would be optimal with no remaining priority for redistribution, as when costless transfers are available. Starting from such a point, we increase the planner's "inequality aversion," or the "price" the planner is willing to pay in order to institute transfers to poorer households. The model allows us to examine the following questions: Relative to an *efficient* pollution control program, which control strategies would be scaled back and which would be strengthened under aversion to inequality?[6] Would the optimal air quality be higher or lower with inequality aversion?

Applications of Social Welfare Functions with Redistributive Objectives

For applied public expenditure analysis, McGuire and Aaron (1969), Aaron and McGuire (1970) and Maital (1973) made advances by proposing a methodology for including differences in valuation of public goods by income class. In a context with a redistributive welfare function, Feldstein (1972) showed how *distributional characteristics* for consumer goods (used here) are useful in tax analysis.

There are few applications with strictly concave welfare functions. The welfare function used here is discussed in Atkinson (1970), and a number of applications from developing countries are presented in Newbery and Stern (1987). In Atkinson's social welfare function, a parameter (ϵ) specifies the planner's aversion to inequality. Atkinson used parameter values of one and two for illustration, and values in this range are typical for applied studies, including the present one. To illustrate, assume that one household has an income double that of another, and that the planner evaluates making transfer from the richer to the poorer, even if something will be lost in the transfer. Then, for inequality aversion $\epsilon = 1$, the planner would be willing to lose up to half of the resources taken from the rich in order to institute the transfer, and for $\epsilon = 2$ she would be willing to lose up to three quarters.[7]

Another strand of the normative literature uses *poverty measures,* a class of welfare functions ignoring the well-being of individuals above a certain threshold of income or well-being. We do not perform alternative calculations with poverty measures, but there are indications that

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the head-count index, would be rather crude in analysis like the present one: It would merely *count* the net number of individuals (or households) who cross the poverty line from below as a result of the policy change.

[6] Hylland and Zeckhauser (1979) argue that distributional objectives should affect taxes, but not program design. They assume that total benefits do not depend on the distribution of income, and thus exclude most cases in which program benefits are normal goods, as in our case.

[7] At wide dispersions in income, implications are greater: In our Java survey data, the relative values of transfers to households in the first and the fifth income quintile is 7 for $\epsilon = 1$, and 45 for $\epsilon = 2$ (We use each quintile's median, see annex table 4). For normative evaluations, Ahmad and Stern use parameters of inequality aversion (ϵ) equal to 0.1 through 2 in tax analysis for India (1987, page 302), Heady and Mitra use $\epsilon = 1$, 2 and 6 (1987). Braverman, Hammer and Ahn use $\epsilon = 0.5$ through (almost) infinity (Korea), Newbery (1987) uses $\epsilon = 1$ and 2, Hughes (1987) uses ϵ equal to 1 for Thailand, stating that 2 gives similar results. In positive analysis, Christiansen and Jansen (1978) views data on the Norwegian tax system as an expression of social preference. They estimate values of $\epsilon = 0.9$ and 1.8, emphasizing the former, and remark that the system reflects moderate inequality aversion.

conclusions based on poverty measures might not be very different.[8] Finally, a policy-oriented literature on *targeting* is distributionally oriented with a motivation similar to ours: viewing a limited set of policy instruments as available for redistributive objectives, one analyzes distributional implications, usually with a poverty measure in the objective function (Besley and Kanbur 1988 is a good example).

Concern for the Distribution of Costs and Benefits in Environmental Policy Analysis

Few applied studies analyze the distribution of impacts of pollution control policies, and to our knowledge none exist which does this in the context of a strictly concave welfare function. However, many view distributional patterns as possible determinants of policy adoption in a political economy model, rather than as inputs in a traditional welfare evaluation. A nonempirical example is Buchanan and Tullock (1975), in the influential "Polluters' profit and political response." They argue forcefully that the lack of success in adoption of environmental taxes is due to the unfortunate political economy of its distributional implications: "In terms of their own private interests, owners of firms in the industry along with employees will oppose the tax. By contrast, under regulation firms may well secure pecuniary gains from the imposition of direct controls." They observed that a public agency charged with protecting the environment would go along in a regulatory approach since it allows greater environmental improvement for a given cost imposed on polluters.

Some studies focus on the distribution of costs for environmentally motivated energy price increases, such as Krupnick et al. (1993), which study gasoline taxes. Whalley and Wigle (1991) and Stephan et al. (1992) employ computable general equilibrium models to analyze carbon limitations. They include analysis of the distribution of costs, the first amongst countries and the latter amongst income groups in a country. Rose et al. (1988) and Wernstedt (1995) are examples of studies that employ input-output models to track the burden of policies to protect natural resource. All of these studies have in common that they do not analyze benefits, let alone their distribution.

Almost all studies that include the distribution of benefits have limited the benefit analysis to physical indicators, such as reductions in pollution concentrations. Thus, the question of how different groups value environmental improvements is not addressed. Pearce's (1980) review concludes that evidence on income elasticities for the willingness-to-pay for environmental improvements is "almost entirely inconclusive."[9] Christiansen and Tietenberg (1985) review studies that, with one exception, use physical measures to impute the distribution of benefits. The exception is Johnson (1980), who employs the method proposed by Aaron, McGuire and Maital, inferring variation in willingness-to-pay from variation in the marginal utility of income.

On the distribution of pollutant measures, Freeman (1972) and many others find evidence that within U.S. cities, poorer households reside in areas with lower air quality (this is a pattern we find in Jakarta as well). Along these lines, there has also been a lively debate (and some careful

[8] Ravallion (1994) reports that poverty measures rank income distributions quite consistently with Atkinson's social welfare functions for inequality aversion parameters as low as $\epsilon = 1$ to 2.

[9] He does not find any study that presents a credible method and results.

studies) on "environmental justice." In the United States, poor and/or minorities are (in some cases at least) over-represented in areas with higher pollution indicators. Sexton et al. (1993) review environmental justice studies on air pollution and associated health risks. Brooks and Sethi (1997) include political economy perspectives. Typically, these studies examine data on pollution levels, rather than changes in control costs and environmental benefits due to policies and choices, which is the emphasis of the present study.

A few interesting observations on the distributional impacts of air pollution control policies may be mentioned. Peskin (1978), in a study of the United States, finds that benefits are concentrated in a few regions in the North East. Control costs are more evenly distributed, so the net beneficiaries will be in minority (he presents national policy adoption as a remaining puzzle). Among his findings are that "those who gain . . . are likely to be nonwhite, low-income, inner city residents," and he comments that these may be likely targets if politicians seek to protect weak groups. Harrison (1977, and in other papers) observes that many cars in rural areas are owned by poor households, and that emission controls in those areas would not yield appreciable air quality improvements. Thus, he argued, a "two-car strategy" with less expensive controls for cars in rural areas would be good for efficiency and equity reasons. We may note that later developments in the United States have some features addressing these patterns: local jurisdictions to some extent shape their own air pollution control strategies. California, with high incomes and air pollution levels, now applies the strictest emission standards in the country.

Turning to the benefit valuation, there is not much empirical evidence on how willingness-to-pay for environmental improvements increases with income. Although environmental quality is typically assumed to be a normal good (that is, the income elasticity of willingness-to-pay for environmental improvements, $\xi_{WTP,I}$, is positive), it is often argued that pollution reductions benefit the poor most because they live in the more polluted areas (see above). These statements are not necessarily inconsistent—since the normality of the good refers to how different income groups would value identical air quality improvements. In fact, if the choice of residential location in part is influenced by air quality, then the less wealthy would live in more polluted areas precisely because their willingness-to-pay for air quality is lower (this is exploited in the hedonic method for empirical estimation of benefits). Empirical results on the willingness-to-pay for environmental improvements are sparse in general, and can in theory be site-specific. Public goods such as pollution levels are in principle "tradable" in a Tiebout type model with migration between sites that offer different amounts of the public good. Within such a model, empirical identification of willingness-to-pay is possible in principle, but applied studies typically yield too little information to differentiate willingness-to-pay by income.

Smith and Huang (1993), in an analysis of estimates from a collection of hedonic models, find that income has a positive significant coefficient in some models of willingness-to-pay (but not all), implying that air quality is a normal good. However, the reporting of the results does not allow deduction of an income elasticity. For air quality improvements in developing countries, Alberini et al. (1994) use survey returns to estimate willingness-to-pay for associated health effects in Taiwan. They find elasticities of willingness-to-pay of 1/3, and also report this to be consistent with some findings from the United States (note that the public good in this context is associated health effects, presumably a subset of all associated effects). Other studies of willingness-to-pay and income in developing countries are not known, and elasticities of 1 are often implicitly assumed in transfers of estimates from other countries. Partial indirect evidence can be found in studies that have estimated "environmental Kuznetz curves": Grossman and Krueger (1995) and Selden and

Song (1994) both find air pollution eventually to fall with GDP growth. This empirical tendency presumably reflects changes both in costs and benefits of environmental protection as income grows. It lends support to the hypothesis that willingness-to-pay increases with income, however, since it indicates that the benefits of environmental improvements eventually increase sufficiently to justify increasing environmental quality.

To summarize, theory would indicate elasticities of willingness-to-pay for air quality greater than zero (normal goods), and possibly greater than one (luxury goods). Based on theoretical reasoning, values close to zero can be judged implausible, since one compares households with widely differing scarcity of market goods that for this reason has very different ability to pay. Moreover, scant empirical evidence can hardly be seen as sufficient to rule out the possibility that elasticities of willingness-to-pay may exceed one.

2. A Welfare Function Approach to Public Goods Provision

The General Framework

Household utility and consumption. We shall use the words household and individual synonymously.[10] Let household h's utility, $u^h = u^h(x^h, d)$, depend on the consumption of n market goods, $x^h = x_1^h, \ldots, x_n^h$, and pollution concentrations, d. For notational simplicity, we assume uniform mixing of pollution, and will later generalize to the case in which households experience differing pollution levels. We furthermore assume that the number of agents polluting the area is large, so that pollution can be modeled as exogenous to the household. Consumption of market goods is chosen by the household to maximize u^h given lump-sum income, I^h, pollution, and prices, $p_1, \ldots, p_n$. We assume separability in preferences between pollution and market goods, so that the household's preferences for an unpolluted environment are not influenced by the relative prices among market goods. The indirect utility function expresses household h's utility as a function of prices, pollution, and income:

$$(1) \qquad v^h(p, I^h, d) = u^h(f^h(p, I^h), d),$$

where $x^h = f^h(p, I^h)$ is a set of Marshallian demand functions and $\partial v^h / \partial d = \partial u^h / \partial d$, by the envelope theorem.

Technology of production and pollution abatement. We assume that pollution abatement technologies can be employed in a polluting production process or embodied in the product itself. Abatement reduces pollutant emissions per unit of output, but also increases the cost of the product.

Examples of abatement in production processes are sulfur scrubbers and filters on smokestacks, wastewater treatment plants, or alternative, less polluting processes. Examples of

[10] Becker's "rotten kid theorem" provides an introduction to conditions under which—in this way—we can allow welfare analysis to abstract from problems of intrahousehold distribution (see Bergstrom 1989).

abatement embodied in consumption goods are unleaded gasoline, catalytic converters and other improvements in cars, or nonphosphate detergents. We do not ignore the possibility that pollution can be reduced without costs, but we shall reserve our parameter denoting abatement, a_j, for the more analytically relevant efforts that reduce emissions further, at a real cost.

For all goods $j = 1,..,n$, we describe costs by a function that satisfies the usual regularity conditions:

$$(2) \quad c_j(a_j,x_j), \text{ with } \partial c_j/\partial x_j > 0,\ \partial^2 c_j/\partial x_j^2 \geq 0,\ \partial c_j(0,x_j)/\partial a_j = 0,\ \partial^2 c_j/\partial a_j^2 > 0.$$

The generalizations here are for analytical convenience. There may be sectors that are at the outset nonpolluting: they are here described as sectors for which emissions reach an insignificant level at a miniscule cost of abatement. Similarly, polluting sectors for which no abatement technology is available are here described as yielding only insignificant reductions in emissions even at high abatement, with the consequence that emissions are not abated to any significant extent.

We integrate this structure in a simple model with fixed coefficients of transformation, by letting the transformation coefficient in each sector be determined by abatement, but independent of output:

$$(3) \qquad c_j(a_j,x_j)=c_j(a_j)x_j$$

Society's resource constraint is:

$$(4) \qquad \Sigma_j c_j(a_j) \sum_{h\in H} x_j^h = 0.$$

It is possible, of course, to think of a wide range of goods and services as nonpolluting, and for these abatement will of course be zero. To suit convention in the public finance literature, it would be natural to choose such a good as the numeraire good (its price of one could thereby be held constant throughout the exercise).

We shall later introduce the possibility that a pollution control strategy influences costs for a range of goods rather than for one good. In that case, the pattern of cost change is determined by the domain of the policy and by repercussions through intermediate deliveries between sectors. As an example, a transportation pollution control strategy can be limited in domain to passenger transport, or it can be applied to transport more generally. In the latter case, it increases costs of nontransport goods and services as well, according to the use of transportation as an input, directly and indirectly, in the various sectors. To simplify presentation in this analytical section, we assume that a pollution control strategy j increases the cost of good j only.

We shall assume that consumers face prices equal to marginal costs:

$$(5) \qquad p_j = c_j(a_j)$$

so that there are no taxes or subsidies in the economy.[11]

Pollution. Pollution concentration is a function of total pollutant emissions in area,

(6) $$d = d(e), \quad e = \sum_j \sum_h e_j(a_j)\, x_j^h,$$

where $e_j(a_j)$ is the emission coefficient for good j when the technology is a_j. We make the usual regularity assumptions, and assume $\partial e_j / \partial a_j < 0$ for $e_j > 0$.

Policy instruments. An important topic in environmental economics has been the choice of policy instrument and our treatment here is very brief (discussions are found in Baumol and Oates 1988 or in Eskeland and Jimenez 1992, for an emphasis on developing countries). Abatement in any sector may clearly be induced either with regulation (say emission standards) or with taxes, and the essence of our modeling is that in either case the costs will accrue to the consumers facing price increases for their consumption goods. There is an important shortcoming of our analysis, however, if one assumes that abatement is induced by revenue-yielding instruments, such as emission taxes, or auctioned emission permits. In this case, one would complement our analysis with the income distribution effects for the proceeds, say through changes in public expenditures. As is highlighted in public finance texts and in the recent literature on green (and double) dividends, the use of the proceeds from environmental taxes should be subject to standard public finance principles. As shown in Sandmo (1975), optimal environmental taxes eliminate distortionary taxation if they raise exactly what is needed for public budgets.

While instruments and control strategies could be sector-neutral, our analysis covers more specific strategies, leaving more instruments in the tool-chest. In the empirical section, we first analyze strategies addressing emissions from household consumption of energy and transportation services directly. Subsequently, we analyze strategies influencing all stages of production and consumption.

A welfare function. We want an analytical framework allowing variation in how one values one individual's change in utility compared to that of another. For this, we use a welfare function $w(v^1, v^2, \ldots, v^H)$ defined over each individual's utility. We assume the planner sets abatement in each sector (for instance directly by emission standards) to maximize social welfare. With constant returns to scale and prices equal to marginal costs (5), society's resource constraint (4) is satisfied (it is the sum of private budget constraints, which are behind the indirect utility functions). We also use (6), describing how abatement influences pollution. In optimum, the marginal welfare effect of abatement in each sector equals zero:

(7) $$\frac{dw}{da_j} = \sum_{h \in H} \beta^h \left[-x_j^h \frac{\partial c_j}{\partial a_j} + \left(\frac{\partial v^h}{\partial d} \Big/ \frac{\partial v^h}{\partial I^h} \right) \frac{dd}{da_j} \right] = 0, \; all \; j \in J,$$

[11] If there are taxes and subsidies in the economy, then environmental policies will influence net tax proceeds through resulting changes in equilibrium demands. This is treated in Sandmo (1975), in the recent "double dividend" literature (see, for instance, Goulder 1994, and in Eskeland 1996). General insights are limited to contexts in which the tax structure is optimal under specified objectives and constraints.

where we have used Roy's identity, $\partial v^h / \partial p_j = -x_j^h \partial v^h / \partial I^h$. Also, we have introduced simplifying notation for the marginal value to the planner of increasing household *h's* disposable income,

$$\beta^h \equiv \frac{\partial w}{\partial v^h}\frac{\partial v^h}{\partial I^h},$$

and J is the set of possible abatement strategies (for instance the set of polluting goods and services, if strategies are output-based).

Inside the brackets of (7) are the net benefits accruing to household *h*, with the first term describing the control costs accruing to household *h*. These are proportional to *h*'s consumption of good *j*, and the proportionality factor is the increase in the good's unit cost. The second term describes benefits associated with a marginal unit of abatement, in terms of *h*'s willingness-to-pay for pollution (i.e., the willingness-to-pay for pollution reductions, but with the opposite sign).[12] Since the welfare function represents a weighted sum of net benefits to households, we may use the term welfare weights for the $\beta^h s$.

Efficiency. If the planner has available instruments for costless transfers of income between households, then all the social welfare weights will be equalized. Then, it is not attractive to let redistributive objectives influence the use of other instruments, such as environmental policies. Since potential compensation via costless transfers can underpin the use of social welfare weights that are uniform across individuals, analysis which uses uniform weights is often described as using the compensation criterion (for an exposition, see Varian 1984, page 169).

With uniform welfare weights, the optimality condition (7) simplifies to:

$$\sum_{h\in H}\left(\frac{\partial v^h}{\partial d} / \frac{\partial v^h}{\partial I^h}\right)\frac{dd}{da_j} = \sum_{h\in H} x_j^h \frac{\partial c_j}{\partial a}. \tag{8}$$

To see that (8) represents the Samuelson condition for optimal provision of a public good (Samuelson 1954), notice that the right-hand side is the marginal cost of abatement ($\partial c_j/\partial a_j$ is the marginal increase in *unit* cost for good *j*). The marginal cost of environmental improvements is obtained on the right-hand side when dividing by the marginal effect on the pollution indicator (dd/da_j).

Consideration of the distribution of costs and benefits. Assume now that we start our policy assessment at a point where aggregate marginal benefits equal aggregate marginal costs (i.e., using uniform weights, as in equation 8), and ask what is the marginal effect of a_j on welfare under an alternative set of welfare weights β:

$$\frac{dw}{da_j} = \sum_{h\in H}\beta_h\left[\left(\frac{\partial v^h}{\partial d} / \frac{\partial v^h}{\partial I^h}\right)\frac{dd}{da_j} - x_j^h\frac{\partial c_j}{\partial a_j}\right]. \tag{9}$$

[12] To see that willingness-to-pay is $-\partial v^h/\partial d/\partial v^h/\partial I^h$, totally differentiate v^h, set $dv^h=0$, and solve for dI^h/dd.

We may subtract (8) from (9) to check whether a marginal increase in strategy j is attractive under the welfare weights β:

(10)
$$\frac{dw}{da_j} \underset{<}{\overset{>}{=}} 0 \Leftrightarrow$$

(11)
$$\frac{\sum_{h\in H}\beta^h\left(\frac{\partial v^h}{\partial d}/\frac{\partial v^h}{\partial I^h}\right)-H\overline{\left(\frac{\partial v}{\partial d}/\frac{\partial v}{\partial I}\right)}}{H\overline{\left(\frac{\partial v}{\partial d}/\frac{\partial v}{\partial I}\right)}} \underset{<}{\overset{>}{=}} \frac{\sum_{h\in H}\beta^h - H\overline{x}_j}{H\overline{x}_j},$$

where the bars denote averages over households and H is the number of households. In (11), we have divided by equation (8).

The right-hand expression is the distributional characteristic for good j. Distributional characteristics are used in tax incidence analysis: the greater a good's distributional characteristic the more will its tax proceeds be collected from lower-income households.[13] The left-hand term is an analogous characteristic for a public good: the pollution reduction benefits. When comparing the distributional characteristics for private and public goods, we may note that a vector of quantities in the former has been replaced by a vector of values in the latter. This asymmetry reflects the fact that for a private good, the price is given exogenously to the household, and household preferences are reflected in the quantities they choose. For a public good, in contrast, the quantity is given exogenously to the household, and household preferences are reflected in their willingness-to-pay.

Proposition: Starting from a point at which aggregate marginal benefits equal aggregate marginal costs for control strategy j, a welfare function would ask that more of a strategy be applied if and only if the distributional characteristic of the benefits exceed the distributional characteristic of the costs, and vice versa. (The proof is given above).

Another way of stating this result is that additional (less) pollution control with strategy j is attractive when the welfare weights have a greater (lower) covariance with the marginal benefits than with the control costs.

Notice that we can also compare the right-hand side of (11) for different pollution control strategies, in effect checking whether one strategy can be strengthened relative to another to redistribute control costs, keeping pollution constant.

Generalization: Policy affects a range of prices, and people experience different pollution levels. These generalizations are quite intuitive, and we limit the exposition to the results. For the first generalization, we denote a pollution control strategy by a_k (where k is not necessarily a commodity) and let the cost implications faced by consumer h be described by $\sum_{j=1}^{n} x_j^h \, dc_j / da_k$.

[13] Distributional characteristics for private goods are shown to be useful in tax analysis under general welfare functions (Feldstein 1972, page 33). Besley and Kanbur (1988) show how simpler measures, such as the poors' share in a good's aggregate consumption, can be useful when poverty measures are used.

For exposure levels that differ among households, we have a case with provision of the public good varying by area. The policy relevant generalization is when pollution levels in different areas unavoidably are addressed by the same policy lever, as when pollution drifts across boundaries, or when one emission standard applies to cars in several areas. In other cases, the above conditions can be used for each area individually. We give the pollution indicator an individual superscript h to specify the public good provision experienced by household h.

The modified Samuelson condition and the analogue to equation (11) are, respectively:

(12) $$\sum_{h\in H}\left(\frac{\partial v^h}{\partial d^h}/\frac{\partial v^h}{\partial I^h}\right)\frac{dd^h}{da_k}=\sum_{j=1}^{n}\sum_{h\in H}x_j^h\frac{dc_j}{da_k}$$

(13) $$\frac{dw}{da_k}\ \substack{>\\=\\<}\ 0 \Leftrightarrow$$

$$\frac{\sum_{h\in H}\beta^h\left(\frac{\partial v^h}{\partial d^h}\Big/\frac{\partial v^h}{\partial I^h}\right)\frac{dd^h}{da_k}-H\overline{\left(\frac{\partial v}{\partial d}\Big/\frac{\partial v}{\partial I}\right)\frac{dd}{da_k}}}{H\overline{\left(\frac{\partial v}{\partial d}\Big/\frac{\partial v}{\partial I}\right)\frac{dd}{da_k}}}\ \substack{>\\=\\<}\ \frac{\sum_{j=1}^{n}\left(\sum_{h\in H}\beta^h x_j^h-H\bar{x}_j\right)\frac{dc_j}{da_k}}{\sum_{j=1}^{n}H\bar{x}_j\frac{dc_j}{da_k}}.$$

The distributional characteristics in this case are associated with a particular strategy k, and how this strategy influences the provision of the public good and the costs of private goods, respectively.

Income levels and willingness-to-pay. We are interested in how the willingness-to-pay for environmental improvements vary with household income and suppress individual superscripts, for simplicity:

(14) $$\frac{\partial\left(-\frac{\partial v}{\partial d}\Big/\frac{\partial v}{\partial I}\right)}{\partial I}=\frac{-\frac{\partial^2 v}{\partial d\partial I}\frac{\partial v}{\partial I}+\frac{\partial v}{\partial d}\frac{\partial^2 v}{\partial I^2}}{(\partial v/\partial I)^2}\Rightarrow\xi_{WTP,I}\equiv\frac{\partial^2 v}{\partial d\partial I}\frac{I}{\partial v/\partial d}-\frac{\partial^2 v}{\partial I^2}\frac{I}{\partial v/\partial I}.$$

In the latter expression, we have introduced a term for the elasticity of willingness-to-pay with respect to income, $\xi_{WTP,I}$. The two expressions on the right-hand side in the latter equation are themselves elasticities with respect to income. The first describes the marginal disutility of pollution as it changes with income, the latter the marginal utility of income as it changes with income. Equation (14) illustrates clearly the logic behind one method proposed in incidence analysis: By assuming that the effect of the public good on utility does not vary with income (i.e.,

$\partial^2 v / \partial d \partial I = 0$), one can associate all variation in willingness-to-pay with variation in the marginal utility of income (i.e., due to $\partial^2 v / \partial I^2$).[14]

Specifying Functional Forms for Empirical Application

Preferences. As stated earlier, we assume that preferences are separable between the consumption of market goods and pollution, d, and we let $\Psi(I,p)$ be an indirect subutility function defined over the consumption possibilities for market goods. We propose a simple functional form allowing parametric variation in $\xi_{WTP,I}$:

(15) $$v(I,p,d) = \psi - d\psi^{\alpha+1} = \psi(I,p)\left(1 - d\psi(I,p)^{\alpha}\right)$$

Utility equals the value of the subutility function $\Psi(I,p)$ when the pollution indicator d is zero. The non-negative pollution indicator is calibrated such that pollution 'removes' part of (not all) the utility that money would otherwise buy.[15] For the willingness-to-pay for pollution reductions, we have:

(16) $$-\frac{\partial v}{\partial d} / \frac{\partial v}{\partial I} = \frac{\psi^{(\alpha+1)}}{\frac{\partial \psi}{\partial I}\left[1 - d(\alpha+1)\psi^{\alpha}\right]}.$$

To represent preferences, the material consequence is how a utility function ranks a vector I,p,d. The separability assumption ensures that monotone transformations of Ψ and d will not affect the ranking of consumption possibilities, described by I,p. Such transformations do, however, in combination with the parameter α, affect the marginal rate of substitution between market goods and pollution reductions. Thus, we may fix Ψ and use α to describe the relationship between the valuation of the public good and consumption possibilities for market goods. For Ψ, we choose the indirect compensation function, $\Psi(q,p,I) = e(q,v(p,I))$, where e is the expenditure function. The indirect compensation function describes how much money one needs at prices q to be as well off as if facing prices p with income I. With respect to p and I, the indirect compensation function behaves like an indirect utility function, and has the advantage that it is defined exclusively over observable arguments (Varian 1984). We have: $\partial\Psi/\partial p_j = \partial e/\partial u \partial v/\partial p_j = -x_j$, $\partial\Psi/\partial I = \partial e/\partial u \partial v/\partial I = 1$ and:

(17) $$-\frac{\partial v}{\partial d} / \frac{\partial v}{\partial I} = \frac{I^{(\alpha+1)}}{1 - d(1+\alpha)I^{\alpha}}, \text{ and}$$

---

[14] See Aaron and McGuire (1970), Maital (1972), and Johnson (1980) for an environmental application.

[15] We assume $d < 1$. Then, pollution reduces household utility by a positive share less than one for all households, as long as $\alpha < 0$, i.e., as long as air quality is not a luxury good (below). We also make policy simulations with $\alpha = 1$ (or $\xi_{WTP,I} = 2$), and then check that even the richest have positive utility and positive marginal utility of income. The latter restriction, $1\text{-}d(1+\alpha)Ih^{\alpha}>0$, is the stricter of the two.

(18) $$\xi_{WTP,I} = 1 + \frac{\alpha}{\partial v / \partial I}.$$

Marginal utility of income equals one if there is no pollution and will be close to one in most of the cases we discuss.[16]

The pollution indicator. Let air pollution concentrations be modeled as quadratic in total emissions per square kilometer in the area, A. This indicator satisfies two reasonable requirements: First, the indicator does not change if areas with the same emissions per square kilometer are joined to together or studied separately. Second, emission reductions reduce the pollution indicator more the higher are emissions per square kilometer.[17]

(19) $$d = \frac{k}{2}\left(\frac{e}{A}\right)^2,$$

where k is a scaling factor used to calibrate the damages from pollution.

For the effect of abatement strategy j on emissions, we make the simplifying assumption that abatement does not influence the demand for the pollution good. This simplification does not influence the substance of our analysis, since we calibrate the aggregate net benefits for each strategy to be zero as a starting point for our analysis (using equation 8). A similar simplification is not used in the analysis of control costs, because the envelope theorem in that case allows us to ignore demand responsiveness. The marginal effect of strategy a_j on the pollution indicator is:

(20) $$\frac{dd}{da_j} = \frac{ke}{A^2}\frac{de}{da_j} = \frac{ke}{A^2}\frac{\partial e_j}{\partial a_j}\sum_{h \in H} x_j^h .$$

The welfare function. Let us choose a constant elasticity welfare function (Atkinson 1970) for which:

[16] The exception is wealthy households when air quality is a luxury good and there is much pollution. Pollution will be calibrated to represent 5 percent of income to the median household in the most polluted area, and we will tabulate $\xi_{WTP,I}$ for households with marginal utility of income = 1.

[17] This representation of pollution concentrations is merely meant to be illustrative. The important implication is that the marginal benefits of emission reductions, ceteris paribus, are increasing in emissions per square kilometer. For empirical measures of damages, a pollution indicator would probably be convex, as is ours, or proportional. Dose response functions for health effects, for instance, will often be proportional or proportional after a threshold effect, and the latter would make a summary measure strictly convex. In principle, damage functions could also approach a concave shape at high pollution levels (if enough damage is done, then there are no additional damages from additional pollution). While other functional forms should be tried, our application yields reasonable implications: Dividing Jakarta into five sections, Central Jakarta is most polluted. We find it plausible to assume that, had the exposed population been the same, then the marginal benefits from emission reductions would be highest in Central Jakarta due to the higher pollution levels. A strictly convex damage function is also necessary to reflect the political reality of ambient standards (and also how most people think about pollution): urgency of pollution reductions is increasing in pollution levels. Concavity, while hard to justify for practical reasons also, would have excluded the possibility of marginal analysis, which is exploited in our paper (see, for instance, Baumol and Oates 1988).

$$\frac{\partial w}{\partial v^h} = (v^h)^{-\epsilon} \tag{21}$$

The welfare function is linear in individual utilities for ϵ equal to zero, and transfers to the poor from the rich are valued increasingly as ϵ approaches infinity. In terms of the welfare effect of income transfers, we have:

$$\beta^h = \frac{\partial w}{\partial v^h}\frac{\partial v^h}{\partial I^h} = (v^h)^{-\epsilon}\left(1 - (1+\alpha)d\, I^{h\alpha}\right) \tag{22}$$

Notice that the public good is a determinant of how useful additional income is to one household as opposed to another. Thus, ϵ equal to zero does not make the welfare function neutral to transfers, even though it will be linear in individual utility levels. However, for ϵ equal to zero, all the variation in the welfare weights β represents differences among households in their valuation of income transfers due to pollution (and in our empirical analysis these differences are minor).

3. Data and Results: The Incidence of Air Pollution Control Policies

SUSENAS 1990 is a household consumption survey from the Central Bureau of Statistics in Indonesia. The survey includes consumption items as "expenditure" even when no purchase is involved (such as own production of food and fuel), and total household expenditure therefore provides a good income-proxy for purposes of welfare analysis. On Java, a total of 16,328 households have completed information on expenditures and income, including details on household energy and transportation consumption. Our analysis is concentrated on Jakarta, for which the data allowed subdivision in five administrative areas, or *Kabupatens*: South, North, Central, East, and West. We also report results including "rest of Java" to examine the effects of strategies that include large rural communities. Data on population (1990 census) and area are also from the Bureau of Statistics. For the results on control strategies that include productive sectors, a 1985 input-output table is used. Emission coefficients are from Weaver and Reale (1994), and Eskeland, Jimenez and Liu (1998).

Distributional Characteristics of Costs for Strategies Addressing Emissions from Consumption

In this section we compare the distribution of abatement costs for alternative control strategies. As explained earlier this can be done by comparing distributional characteristics for different pollution goods (the right-hand side of equation 11) or more complex strategies (the right-hand side of equation 13). This provides the incidence analysis that complements cost-effectiveness analysis, i.e., when targeted pollution reduction are exogenously set (for instance because little is known about benefits).

Consumption activities that contribute directly to emissions at the household level are mainly household energy use and passenger transportation. As is seen in Table 1, expenditure shares are rising with income for transport, and declining with income for energy. By implied income elasticities, private and public transportation represent luxury goods, while energy is less income elastic.[18]

Table 1: Household Expenditure Shares[a]

	Jakarta			Rest of Java		
	Transport		*Energy*	*Transport*		*Energy*
	Private	*Public*		*Private*	*Public*	
Quintile 1[b]	0.0	2.4	12.5	0.2	1.2	10.9
Quintile 2	0.0	5.8	9.0	0.4	1.3	9.1
Quintile 3	0.0	6.8	8.3	0.8	1.5	8.0
Quintile 4	0.3	7.6	7.9	1.7	2.0	7.0
Quintile 5	3.1	6.2	6.5	4.8	2.6	5.7

a. Greater detail shown in Annex Table 2.

b. The quintiles are, throughout, "Java-quintiles," and a household's total expenditure is used as proxy for income.

To make income levels by quintile comparable, 'Java quintiles' have been used throughout, whether the area is Java, Jakarta, or rest of Java.[19] For transport, we may note that Jakarta households at all income levels have higher expenditure shares for public transport and lower for private transport than households from the rest of Java. For energy consumption, patterns of expenditure are quite similar in Jakarta and rest of Java.

Table 2 shows the distributional characteristics for control costs from consumption-oriented transport- and energy strategies. As shown in the previous section, distributional characteristics can be thought of as welfare-weighted cost measures, and give good insight into how the planner's assessment of control strategies is affected by an increased priority for transfers to the poor. The distributional characteristics shown here (the parameter of inequality aversion ϵ increasing from one to two compare) with distributional characteristics of one that would prevail with a linear welfare function, or ϵ equal to zero (this statement is an approximation in the presence of pollution).[20]

[18] Estimated demand systems with price elasticities would be useful in welfare calculation for discrete price changes, but would have to be differentiated by income group to be useful in the context of this study. For marginal analysis, performed here, such parameter estimates are not required. Deaton's method for estimation of demand parameters exploiting spatial variation was attempted, but with generally unconvincing results for more complex demand systems. Estimated income elasticities performed better, but do not add much to the analysis when it can be based on large samples of household budgets, as is ours.

[19] Income levels are higher in urban areas, but many prices are lower in rural areas, a difference we do not take account of here. Ravallion and van de Walle (1991) suggest the cost of living may be about 10 percent higher in urban areas, for consumption baskets applicable in the vicinity of the poverty line.

[20] When reflected in policy, aversion to inequality will result either in costly transfers (as here) or in equalization of incomes. Thus, our sensitivity analysis with respect to inequality aversion can also be interpreted as sensitivity analysis with respect to the marginal cost of making transfers. We may illustrate the effects of our parametric variation as follows: At $\epsilon = 1$, the marginal social valuation of income to the poorest quintile is 7 times that to the highest quintile. At $\epsilon = 2$, the corresponding figure is 45 (see Annex Table 4).

Table 2. Distributional Characteristics of Control Costs

	Jakarta		Java	
	$\epsilon = 1$	$\epsilon = 2$	$\epsilon = 1$	$\epsilon = 2$
Total energy	0.72	0.55	0.72	0.55
Total transport	0.61	0.39	0.32	0.12

Throughout, the distributional characteristic for the energy strategy is higher than for the transport strategy. This reflects the fact that energy expenditures increase less with income than expenditures on transport (see Table 1, and Annex Tables 1 and 2 for more detail). Thus, a reduced concern for wealthier consumers reduces the weighted incidence of costs for the transportation relative to the energy strategy. This means that if one introduces redistributive objectives in the choice of control strategy when merely looking at the distribution of *control costs*, it will strengthen the transport strategy, and scale back the energy strategy. Such a reallocation of abatement efforts could be made in a way holding total pollution constant, justifying the somewhat higher total abatement costs with the implied transfer of control costs from poorer to wealthier households. This distribution-motivated preference for transportation control strategy is even stronger if one studies a control program for all of Java, rather than just Jakarta.

As one might expect, a similar difference exists between control strategies for private transport and public transport (Table 3). Expenditure shares for private transport are rising more sharply with income than they do for public transport, so a reallocation of abatement efforts from public to private transport would benefit the poor.

Table 3: Distributional Characteristics of Control Costs, Transport Strategies

	Jakarta		Java	
	$\epsilon = 1$	$\epsilon = 2$	$\epsilon = 1$	$\epsilon = 2$
Public transport	0.80	0.59	0.41	0.18
Private transport	0.37	0.14	0.21	0.07

At this point, it may be worth comparing results with findings from the United States. Harrison (1977) found that control costs for private car strategies would hurt poor households, particularly in rural areas. Several stylized facts can explain much of the contrast to Java: (i) due to a higher general income level, car ownership reached farther into low-income groups in the United States in the seventies than in Indonesia in the nineties; (ii) in the United States, rural population densities are lower, and self-sufficiency in rural communities is lower, so poor rural households depend more on cars for mobility than on Java. Quite likely, private and public transport are not luxury goods in richer countries, whereas on Java we find both to be, in the sense that expenditure shares are increasing in total expenditures. Importantly, public transport in this data set represents a broad aggregate, likely including luxurious modes such as taxis and plane trips. Thus, it may be the case that expenditure shares for more narrowly defined public services such as tricycle taxis, bus and minibus travel decline with income. These questions, and therefore some more detailed policy problems, cannot be answered with this type of empirical data. For instance, strategies increasing the costs of new cars will probably hurt the poor less than strategies affecting old cars and the fuel cost element. Similarly, buy-back programs that get old cars voluntarily off the street *benefit* owners of old cars, hurting those that would by them (and those who fund the buy-backs).[21]

Table 4 shows the effect of inequality aversion on more narrowly defined energy strategies. For some fuels, the weighted incidence of control costs is hardly diminished by inequality aversion, showing that these to a great extent are used also by lower-income households. In Jakarta, coal, firewood and kerosene are relatively important for the poor. When strategies for Java are considered, coal and kerosene do not play such an important role in the consumption basket of the poor.[22]

Table 4: Distributional Characteristics of Control Costs, Energy Strategies

	Jakarta		*Java*	
	$\epsilon = 1$	$\epsilon = 2$	$\epsilon = 1$	$\epsilon = 2$
Electricity	0.61	0.42	0.43	0.22
Coal	1.32	1.36	0.72	0.42
Firewood	1.07	0.96	1.00	0.89
Kerosene	1.00	0.92	0.74	0.54
Gas	0.39	0.14	0.17	0.03
Total energy	0.72	0.55	0.72	0.55

Electricity and gas (including piped and bottled gas) are luxury goods, so strategies for these have smaller distributional characteristics. Thus, electricity and gas strategies would receive increased relative emphasis if control programs were modified with redistributive objectives in mind.[23] For electricity, as in the case for car ownership, we probably see an effect markedly different from what one would observe in wealthier countries, where electricity connections and car ownership reach farther down in the income distribution. Commodities with threshold effects like these allow incidence patterns to vary greatly between countries at different income levels (see Berndt and Samaniego 1984).

[21] Concerns for income distribution often influence arguments over control strategies. One-day driving bans are often popular for their alleged 'fairness' (Eskeland and Feyzioglu 1997). An argument behind buyback programs (always small in scale) and grandfathering clauses for old vehicles is that they shield households one would not want to hurt with additional costs. For car strategies, examples of the greater detail of alternatives available can be found in Harrison (1977) and Eskeland (1994).

[22] Pitt (1985) also finds that kerosene, coal and firewood are not luxury goods on Java.

[23] For electricity, pollution is associated with generation (we assume 50 percent is coal fired power, fifty percent is clean, see Eskeland et al. 1998). This in contrast to other "polluting goods," where pollution literally is associated with their consumption. This perspective is the relevant one if the costs of making electricity production cleaner are passed on to households according to consumption. Even for *gas*, a relatively clean fuel, policies making its use more expensive could be chosen to make it cleaner (mandating cleaner stoves, for instance, or addressing leakages). If the policy considered is subsidies to induce substitution to gas as a cleaner fuel, the income distribution argument is reversed: as the fuel is mostly used by wealthier households, poor households would not benefit much from the transfer effect of the subsidy (for such instruments, incidence analysis for the funding mechanism is also warranted).

Control strategies applied to Jakarta. As emphasized in the analytical section, analysis of distributional implications should focus on the distribution of control costs *and* benefits. Our modeling of benefits has two important limitations. First, we want to be able to link control strategies to improvements in air quality experienced by households. Our approach here has been to focus on Jakarta as a polluted area, on emissions from polluting goods as services, and on residential location as determinant of exposure. The SUSENAS survey data allows the localization of households to the five *Kabupatens* of Jakarta (Central, North, East, South and West), as well as rest of Java. Treating the surveyed households as representative for the population in each area, a pollution indicator for each area was created.[24] Table 5 shows some summary statistics for the six areas.

Second, there is great uncertainty about the extent to which the willingness-to-pay for pollution reductions increases with household income. We rely extensively on sensitivity analysis with respect to this parameter. We shall view a unitary income elasticity as a central case of reference, the one for which a households exposed to the same pollution levels would be willing to pay the same *share* of their income for a given ambient improvement. Notable features of the unitary income elasticity are: (i) a large proportion of total benefits are received by wealthier households and (ii) total benefits are invariant to redistribution of incomes.

Table 5: Summary Statistics, Jakarta and Java

	Household mean income[a]	*Coefficient of variation (percent income)*	*Population (thousand)*	*Population density (pers/km2)*	*Pollution Indicator*	*Pollution Value, (percent income*[b]
Central Jakarta	294	78	1,075	21,939	1.00	5.00
North Jakarta	377	120	1,362	8,966	0.31	1.56
East Jakarta	297	78	2,064	10,981	0.33	1.65
South Jakarta	338	64	1,905	13,050	0.47	2.34
West Jakarta	346	64	1,820	14,106	0.68	3.41
Rest of Java	117	95	100,547	783	0.03	0.13

a. A household's total expenditure is used as proxy for income (thousand rupiah per month).

b. Pollution value is calibrated to five percent of incomes in the most polluted areas (Central Jakarta). Elasticity of willingness-to-pay is assumed to be one in this table.

24 The indicator is calculated as follows: total use of each fuel in the area is calculated as total use by the households surveyed multiplied by the ratio of the area's population to the surveyed population. A fuel-specific emission factor represents particulate emissions, or dust, the pollutant of greatest concern in Jakarta (see Ostro 1994; Weaver and Reale 1994). Total area emissions per square kilometer are then calculated for each area (Equation 6). The pollutant indicator (Equation 19) is calibrated to reduce the utility of the median household in Central Jakarta, the most polluted area, by 5 percent. This primitive indicator abstracts from multiple pollutants, background levels, variation within areas and dispersion between areas. The representation of Jakarta as radically more polluted than a population-weighted average for the rest of Java appears reasonable, as does the relative ranking of the five Kabupatens in Jakarta. The treatment of "rest of Java" as one region is in part motivated by the fact that Surabaya, the second largest city, was absent from the data set.

Similarly, low income elasticities would imply that pollution damages reduce the utility levels of poor households quite dramatically, if total pollution damages are to represent a significant share of total income. In our calculations, we calibrate environmental damages to reduce the utility levels of the median household in Central Jakarta by 5 percent (the most polluted area, see the last two columns). Under the assumption of unitary $\xi_{WTP,I}$, air pollution reduces utility levels for all households in Central Jakarta by five percent. If the income elasticity is reduced to one half, in contrast, the poorest quintile in the area will have its utility level reduced by 7.6 percent due to pollution, and at $\xi_{WTP,I} = 0.1$, by 10.5 percent (Annex Table 3).

Table 6 shows the distributional characteristics of costs and benefits of energy and transport strategies for Jakarta. For parameter values $\epsilon = 1$, $\xi_{WTP,I} = 1$, we will find distributional characteristics for control costs of 0.72 for energy and 0.61 for transport, as in Table 2. The distributional characteristics of the benefits are 0.72 and 0.71, respectively, so that the distributional characteristic for net benefits is zero for energy and positive transport. Given these parameters the redistributive objectives result in neutrality on the margin to the energy strategy, and a strengthening of the transport strategy (the sign for net benefits is in the third column in each cell). Positive distributional characteristics for net benefits is more likely for a lower income elasticity of willingness-to-pay, $\xi_{WTP,I}$, since a lower income elasticity allocates a greater proportion of the benefits to poorer household. Variation in $\xi_{WTP,I}$ has only an insignificant effect on the distributional characteristics of control costs, through the marginal utility of income. Thus, there is a general tendency for the distributional characteristics of net benefits to be positive towards the right in the tables.

Table 6: Distributional Characteristics, Costs and Benefits, Jakarta[a]

	$\xi_{WTP,I} = 2$			$\xi_{WTP,I} = 1$			$\xi_{WTP,I} = 0.5$			$\xi_{WTP,I} = 0.25$			$\xi_{WTP,I} = 0.1$		
	C	*B*	*Net*	*C*	*B*	*Net*	*C*	*B*	*Net*	*C*	*B*	*Net*	*C*	*B*	*Net*
$\epsilon = 1$															
Total energy	0.71	0.30	—	0.72	0.72	0	0.71	0.87	+	0.71	0.95	+	0.71	0.99	+
All transport	0.60	0.31	—	0.61	0.71	+	0.61	0.86	+	0.60	0.94	+	0.60	0.99	+
$\epsilon = 1$															
Total energy	0.55	0.15	—	0.55	0.53	—	0.55	0.73	+	0.54	0.85	+	0.54	0.93	+
All transport	0.39	0.16	—	0.39	0.52	+	0.38	0.73	+	0.38	0.84	+	0.37	0.92	+

a. Each cell in the table assumes a parameter for the income elasticity of willingness-to-pay for pollution reductions, and for the inequality aversion of the welfare function. A plus (minus) highlights that the distributional characteristic of benefits, B, is greater (smaller) than that for costs, C, so that the strategy would be strengthened under those distributional weights.

At low elasticities of willingness-to-pay (to the right in the table) inequality aversion would lead to a strengthening of both strategies, while both would be scaled back if pollution reduction is a luxury good ($\xi_{WTP,I} = 2$). For unitary $\xi_{WTP,I}$, there are interesting differences between the strategies, however. Here, distributional concerns would lead us to reduce the emphasis on emission control from household energy use, but increase the emphasis on transportation control strategies. Thus, the tendency observed in Table 2, which reflect steeper Engel curves for transport than for energy, are also important in net benefit assessments.

We may observe that the two strategies are almost identical in terms of the distributional characteristics of benefits, so an incidence analysis limited to control costs would be sufficient if only the balance between the two strategies were the subject of analysis. What net benefit analysis adds is the possibility of identifying the range in which redistributive objectives would raise the optimal air quality ($\xi_{WTP,I} = 0.5$ or smaller) or reduce it ($\xi_{WTP,I} = 2$ or larger).

Control strategies applied uniformly across Java. What would the results be if strategies had to be applied uniformly across Java? First, note that it is always desirable, from an *efficiency* point of view, to reduce emissions only from sources that cause air quality problems. On the other hand, for administrative or other reasons, some strategies can only be implemented uniformly across a greater area, in this case assumed to be the entire island of Java.[25] Again, we assume that such strategies are pursued until the point where aggregate marginal benefits equal marginal costs before we turn to the implications of introducing inequality aversion, using $\epsilon = 1$ and 2 (Table 7).

Table 7: Distributional Characteristics, Costs and Benefits, Java

	$\xi_{WTP,I} = 2$			$\xi_{WTP,I} = 1$			$\xi_{WTP,I} = 0.5$			$\xi_{WTP,I} = 0.25$			$\xi_{WTP,I} = 0.1$		
	C	*B*	*Net*	*C*	*B*	*Net*	*C*	*B*	*Net*	*C*	*B*	*Net*	*C*	*B*	*Net*
$\epsilon = 1$															
Total energy	0.72	0.11	—	0.72	0.26	—	0.72	0.33	—	0.72	0.36	—	0.72	0.38	—
All transport	0.32	0.11	—	0.32	0.26	—	0.32	0.32	0	0.32	0.36	+	0.32	0.38	+
$\epsilon = 1$															
Total energy	0.55	0.02	—	0.55	0.07	—	0.55	0.10	—	0.55	0.11	—	0.55	0.13	—
All transport	0.12	0.02	—	0.12	0.07	—	0.12	0.09	—	0.12	0.11	+	0.12	0.13	+

The important difference introduced when households outside Jakarta are affected by the strategy is the many poorer, rural households. They experience very small benefits since they are exposed to very low pollution levels.[26] The fact that most of these poor households are unlikely to benefit is reflected in the Table 7; no strategy would be strengthened by inequality aversion unless $\xi_{WTP,I}$ is 0.25 or smaller. Furthermore, energy strategies would be scaled back, even for $\xi_{WTP,I}$ as low as 10 percent.

Table 8 provides net benefit analysis for more narrowly defined transportation strategies, and some tendencies are intuitive. First, control strategies for private transport are favored by redistributive objectives for a greater range of parameters than strategies for public transport. Second, strategies in a Jakarta program are more likely to be favored by inequality aversion than strategies in a Java program. Two new observations: At $\epsilon = 2$, a private transport strategy for Jakarta is favored by redistributive objectives even when $\xi_{WTP,I}$ is as high as two. In a Java program, $\xi_{WTP,I}$ would have to be lower for a private transport program to be favored by inequality aversion, since Engel curves for private transport are not so steep outside Jakarta. Also, in a Java program, public transport strategies would be scaled back by redistributive objectives even for $\xi_{WTP,I}$ as low as 10 percent.

[25] Emission standards for cars must for practical reasons be uniform for large areas, such as Denmark or California. Fuel-oriented strategies and inspection and maintenance programs are also costly to differentiate by area, administratively, but may be implemented for a large metropolitan area such as Los Angeles or Mexico City (see, Harrison 1977; Eskeland and Devarajan 1996). Even for large point sources, emission standards are, perhaps unnecessarily, often national in scope.

[26] Of course, households in rural as well as urban areas may be exposed to indoor air pollution. We focus on outdoor air pollution because a public good gives an obvious case for policy intervention.

Table 8: Distributional Characteristics of Net Benefits, Transport Strategies

	$\xi_{WTP,I} = 2$			$\xi_{WTP,I} = 1$			$\xi_{WTP,I} = 0.5$			$\xi_{WTP,I} = 0.1$		
	C	*B*	*Net*	*C*	*B*	*Net*	*C*	*B*	*Net*	*C*	*B*	*Net*
Jakarta $\in = 1$												
Private transport	0.36	0.30	—	0.37	0.71	+	0.37	0.87	+	0.37	0.99	+
Public transport	0.79	0.32	—	0.80	0.72	—	0.80	0.86	+	0.79	0.98	+
Jakarta $\in = 2$												
Private transport	0.14	0.15	+	0.14	0.52	+	0.14	0.73	+	0.13	0.92	+
Public transport	0.59	0.16	—	0.59	0.52	—	0.58	0.73	+	0.57	0.92	+
Java $\in = 1$												
Private transport	0.24	0.11	—	0.25	0.26	+	0.25	0.32	+	0.25	0.38	+
Public transport	0.41	0.11	—	0.41	0.26	—	0.41	0.32	—	0.41	0.38	—
Java $\in = 2$												
Private transport	0.07	0.02	—	0.07	0.07	0	0.07	0.1	+	0.07	0.13	+
Public transport	0.17	0.02	—	0.18	0.07	—	0.18	0.09	—	0.18	0.12	—

Table 9 displays more narrowly defined energy strategies. The important distinctions in this table prove to be whether environmental benefits are luxury goods, and whether or not a program can be designed for Jakarta alone. When pollution reduction benefits are luxury goods (i.e., at $\xi_{WTP,I} = 2$), no energy strategy is favored by redistributive objectives. For lower elasticities of willingness-to-pay (i.e., at $\xi_{WTP,I} \leq 1$), control strategies for electricity and gas are favored by redistributive objectives in a Jakarta program, but only the gas strategy in a Java program.

Table 9: Distributional Characteristics of Net Benefits, Energy Strategies

	$\xi_{WTP,I} = 2$			$\xi_{WTP,I} = 1$			$\xi_{WTP,I} = 0.5$			$\xi_{WTP,I} = 0.1$		
	C	*B*	*Net*	*C*	*B*	*Net*	*C*	*B*	*Net*	*C*	*B*	*Net*
Jakarta $\in = 1$												
Electricity	0.60	0.30	—	0.61	0.72	+	0.61	0.87	+	0.60	0.99	+
Coal	10.33	0.33	—	10.32	0.66	—	10.32	0.81	—	10.32	0.94	—
Firewood	10.07	0.33	—	10.07	0.65	—	10.07	0.79	—	10.07	0.91	—
Kerosene	10.00	0.31	—	10.00	0.72	—	10.00	0.87	—	10.00	0.99	—
Gas	0.37	0.30	—	0.39	0.71	+	0.39	0.86	+	0.38	0.98	+
Jakarta $\in = 2$												
Electricity	0.41	0.15	—	0.42	0.53	+	0.41	0.74	+	0.40	0.93	+
Coal	10.37	0.16	—	10.36	0.46	—	10.36	0.67	—	10.33	0.89	—
Firewood	0.96	0.16	—	0.96	0.44	—	0.96	0.63	—	0.95	0.82	—
Kerosene	0.92	0.16	—	0.92	0.53	—	0.91	0.74	—	0.90	0.93	+
Gas	0.14	0.15	—	0.14	0.52	+	0.14	0.72	+	0.13	0.91	+
Java $\in = 1$												
Electricity	0.44	0.11	—	0.43	0.26	—	0.44	0.33	—	0.44	0.38	—
Coal	0.72	0.12	—	0.75	0.24	—	0.72	0.30	—	0.71	0.36	0
Firewood	10.00	0.12	—	10.00	0.24	—	10.00	0.31	—	10.00	0.37	0
Kerosene	0.74	0.11	—	0.74	0.27	—	0.74	0.33	—	0.74	0.38	—
Gas	0.16	0.11	—	0.17	0.26	+	0.17	0.32	+	0.17	0.37	+
Java $\in = 2$												
Electricity	0.22	0.02	—	0.22	0.07	—	0.22	0.10	—	0.22	0.13	—
Coal	0.42	0.02	—	0.42	0.06	—	0.42	0.09	—	0.42	0.12	+
Firewood	0.89	0.02	—	0.89	0.06	—	0.89	0.09	—	0.89	0.14	+
Kerosene	0.54	0.02	—	0.54	0.07	—	0.54	0.10	—	0.54	0.13	—
Gas	0.03	0.02	—	0.03	0.07	+	0.03	0.09	+	0.03	0.12	+

Distributional aspects for general strategies addressing production and consumption

Air pollution is caused not only by consumption activities, but also by production. Policies to control air pollution thus may address production activities as well, or simply aim for emissions irrespective of the kind of polluting activity. Since sectors deliver goods and services to each other, even sectors that are not directly affected may experience cost increases if they use inputs from sectors that are affected, directly or indirectly. Strategies to reduce emissions from manufacturing, services and transport will thus create patterns of price changes for a range of consumer goods and services, even if a strategy is designed to reduce emissions only from one or a few subsectors.

Our modeling framework and available data facilitate analysis of these changes via prices for consumption goods. Other channels of influence for the distribution of costs could also be significant, for instance through markets for immobile and heterogenous factors. We assume that factor returns are unchanged, and only trace the consequences of abatement strategies to consumers (who are endowed with lump-sum income) via prices for goods and services. These are modeled by using an input-output table to represent the quantitative impact of intersectoral transactions. Through such transactions, cost increases for general strategies will be "spread" across a range of goods and services, and thereby be less differentiated by sector than is the case for consumption oriented strategies. One would therefore expect the distribution of control costs to be more even, i.e., more closely related to the total consumption expenditures of each household.

Our first step is to design patterns of sector specific cost increases to represent alternative abatement strategies. Three patterns of cost increases are chosen:

- *Energy strategy: a general rise in the cost of using energy;*
- *Transport strategy: a general rise in the cost of transport;*
- *Manufacturing strategy: Sectoral abatement costs as observed in United States.*[27]

The energy strategy may be seen as a mimicking a general, sector-neutral air pollution control strategy, using energy as a proxy for the costs an industry will have in relation to air pollution abatement.[28] Alternatively, it may be interpreted as a strategy directed at emissions associated with energy production and use in the economy. The transport strategy is more specific, addressing transport activities, taking account of the effects on costs among users of transport services. The manufacturing strategy represents a broad and sophisticated control program for manufacturing in a mature phase.[29]

To compare the distributional impact via final consumption, an intermediate step uses the inverted input-output table $(I-A)^{-1}$ to calculate the resulting price increases for a set of nine

[27] Pollution abatement costs are from U.S. Department of Commerce's PACE dataset, see Low (1992).

[28] Energy use is often the basis in emission models. See U.S. EPA's AP-42 (1986) on the technical basis, and Viscusi et al. (1994), and Eskeland, Jimenez and Liu (1998) for use in economic models.

[29] Most sectors in the United States had higher costs in the initial years of pollution control legislation. On this topic, see Jorgenson and Wilcoxen (1990). Two aspects on timing and maturity are: The planner and the polluter learn how to design policies and how to reduce pollution; pollution control is cheaper for new capital than when older equipment is to be modified.

composite commodity groups. The results for each of the three strategies are shown in Table 10. We may notice that the cost implications for the most important commodity group, food, are relatively small for all three control strategies.

Next, the effect of such a pattern of price increases on the cost of the average consumption basket for each income quintile was calculated. The results are shown in Table 11. For all these strategies, the wealthiest quintile faces the greatest increases in the cost of its consumption basket, not only in absolute terms, but in percent. This result is rather intuitive when we recall, from Table 10, the modest price increases for food that the three strategies have in common. Since, according to Engel's law, the expenditure shares for nonfood items are increasing with income, the wealthier use a higher share of their income on the commodities with the higher price increases. Engel's law is quite important in a setting like Java's, since food expenditures average about 60 percent of total household expenditures, and for 63.4 and 48.8 percent for the poorest and richest quintile, respectively (Annex Table 2).[30] Another observation is that, for all the three strategies, the pattern of cost increases is U-shaped, lower for the middle quintiles than for the poorer and richer. The higher increases for the poor appear to be related to two nonfood consumption categories, housing and energy: both have high expenditure shares at lower income levels, and both have high cost-increases under all the three strategies.

Table 10: Pattern of Cost Increases for Three Control Strategies[a]

	Energy strategy	*Transport Strategy*	*Manufacturing abatement*	*Memorandum Item: Average expenditure Share (percent)*
Food	0.13	0.15	0.30	57.1
Alcohol, tobacco	0.33	0.34	1.03	5.7
Public transport	1.05	8.52	0.74	2.2
Private transport	3.51	9.52	2.37	1.6
Energy	6.00	4.35	2.16	7.9
Housing	3.30	1.37	3.36	7.7
Clothing	0.48	0.45	1.73	5.4
Services	0.48	0.74	0.52	6.0
Other	0.65	0.52	2.52	6.3
Total Java consumption basket	1.00	1.00	1.00	100.0

a. Scaled to increase costs of the average Java consumption basket by 1 percent.

30 Engel's law—that the share of income spent on food is declining in income—is one of the few stylized facts repeatedly found in studies of household expenditure patterns. Lluch and Powell (1975) in a study of countries at different income levels, find that expenditure elasticities for food with respect to income tends to fall with GNP per capita, from close to one to less than one half. Thus, even for such a commodity group, incidence will depend on the actual income level and its distribution, and the reliance on an estimated demand system rather than budget data may be fraught with difficulties.

Table 11: Relative Cost Increases for Consumption Baskets, by Quintile[a]

	Income groups (quintiles) Poorer to richer				
	1. Quintile	*2. Quintile*	*3. Quintile*	*4. Quintile*	*5. Quintile*
Transportation controls	0.86	0.80	0.83	0.95	1.32
Manufacturing abatement	0.96	0.93	0.93	0.98	1.13
Energy strategy	10.07	0.95	0.91	0.92	1.08

a. The reported price increase is relative to the price increase for the average consumption basket.

Table 12 shows distributional characteristics for the control costs of the three simulated strategies, including the estimated effects of intersectoral transactions. The weighted incidence of control costs is lower for the manufacturing control strategy than for the energy strategy, and lowest for the transportation strategy. Due to their nonmonotonous incidence patterns (Table 11), a wider range of parameters for inequality aversion was utilized to check for a possible re-ranking of strategies. However, there is a consistent repetition of the result from consumption-based strategies: With redistributive objectives, transportation strategies are strengthened relative to energy strategies, and a manufacturing strategy falls in between, as if it were a blend of energy and transport strategies.

Table 12: Distributional Characteristics of Control Strategies including Productive Sectors

	$\epsilon = 0.1$	$\epsilon = 0.5$	$\epsilon = 1$	$\epsilon = 2$
Transport strategy	0.955	0.79	0.64	0.46
Manufacturing control strategy	0.962	0.82	0.69	0.52
Energy strategy	0.964	0.83	0.71	0.56

In this case, the modeling of benefits cannot be performed, since the impacts in terms of emission reductions cannot be located (manufacturing is spread out, and the input-output table is for Indonesia as a whole). We may, however, utilize a general tendency observed from the analysis of consumption-oriented strategies: The distributional characteristics of benefits do not differ much by strategy (and never so much as to change the balance between strategies). If we assume that the benefit distribution for the three strategies is similar, redistributive objectives lead to a more controls for the transportation sector, less for the energy sector—with the manufacturing strategy in between.

An important general observation is that we can confirm the conjecture that costs for strategies involving production activities would be more evenly distributed—making their distributional characteristics more similar than for strategies which address specific consumption activities.

4. Summary and Conclusion

We develop an analytical framework to analyze how distributional considerations would modify the optimal provision of public goods. The framework weighs each household's *net* benefits with the help of a welfare function, allowing parametric variation in the planner's aversion to inequality (or, equivalently, allowing variation in the cost at the margin of transferring income between households). As a starting point for the analysis, we assumed various pollution control strategies were exploited as they would be when costless transfer instruments are available, i.e., satisfying the Samuelson condition for optimal provision of public goods.

In tax analysis, a tool for income distribution analysis is a private good's distributional characteristic. Our framework uses an analogous measure, the distributional characteristic for public goods, and shows that the two measures are adequate to analyze distributional considerations in the provision of public goods. We also propose a functional form, which—in a maximally simple fashion—allows for parametric variation in how the willingness-to-pay for public goods depend on the level of supply and on household income.

Assuming, we believe realistically, that control costs are distributed by (something like) the polluter pays principle, we first analyzed the distribution of control costs for strategies addressing emissions generated by household consumption. We found that a private transport control strategy distributes control costs more progressively among households than a public transport strategy, and both more progressively than a strategy addressing household energy use.

For three strategies addressing emissions from productive sectors as well, wealthier households would face a share of total control costs that is greater than their share of total consumption expenditure. The reason is that poor household allocate much of their budget to food, and food is a commodity group which is relatively "shielded" from pollution control costs. Also for production-oriented strategies is it the case that transport strategies are more progressively distributed than energy strategies—with a general manufacturing pollution control strategy as an intermediate case between the two.

We also examined the distribution of benefits from air quality improvements, determined by the household's residential location (on which we have data) and by the income elasticity of willingness-to-pay for air quality improvements (for which we rely on sensitivity analysis). At an income elasticity of one, households experiencing the same pollution reduction would value the change in the same proportion to their income, and total benefits are invariant to redistribution of income. At lower elasticities, a low-income family would be willing to pay a greater share of its income for a pollution reduction than would its wealthier neighbors.

Under a unitary elasticity of willingness-to-pay for air quality improvements, inequality aversion leads to less pollution control in general if a Java-wide program is evaluated. This is because the program will include costs to households in rural areas who are poor and do not experience any significant air quality improvements. In a Jakarta program, the balance between strategies change—stricter controls result for transport (and private transport in particular), while less pollution control would result for energy use. Roughly summarized, urban pollution control programs will be strengthened by inequality aversion at income elasticities of willingness-to-pay lower than one—and reduced at elasticities greater than one (in the latter case, the net beneficiaries will mostly be wealthy). Strategies targeting luxury goods (transport) and necessities (energy) modifies the message somewhat, in an intuitive fashion.

The finding that control programs with wide geographical reach are unlikely to be strengthened by inequality aversion is likely quite robust. It rests on the assumption that benefits of air pollution reductions are greater in areas with high levels of air pollution. For urban air pollution control, the important remaining question is how the poor would value air pollution reductions, relative to increased consumption possibilities for market goods. On the balance between urban pollution control strategies, we show that the benefit distribution does not vary much, so that the distributional considerations can be analyzed fairly well merely by comparing Engel-functions for the various pollution intensive goods—assuming that their price increases will finance the respective strategies.

References

Aaron, Henry, and Martin McGuire. 1970. "Public Goods and Income Distribution" *Econometrica* 38(6): 907–920.

Ahmad, Ehtisham, and Nicholas Stern. 1987. "Alternative Sources of Government Revenue: Illustrations from India, 1979–80." In D. Newbery and Nicholas Stern, eds.

Alberini, Anna, M. Cropper, T. Fu, A. Krupnick, J. Liu, D. Shaw and W. Harrington. 1997. "Valuing Health Effects of Air Pollution in Developing Countries: The Case of Taiwan." *Journal of Environmental Economics and Management* 34: 107–126.

Atkinson, Anthony B. 1970. "On the Measurement of Inequality." *Journal of Economic Theory* 2: 244–263.

Atkinson, Anthony B., and N. H. Stern. 1974. "Pigou, Taxation and Public Goods." *Review of Economic Studies* 41(1): 119–128.

Atkinson, Anthony B., and J. E.Stiglitz. 1980. *Lectures on Public Economics.* McGraw-Hill: London, New York.

Baumol, W., and W. Oates. 1988. *The Theory of Environmental Policy.* Cambridge University Press, 2nd ed.

Bergstrom, Theodore, C. 1989. "A Fresh look at the Rotten Kid Theorem--and Other Household Mysteries." *Journal of Political Economy* 97(5): 1138-59.

Berndt, E.R., and R. Samaniego. 1984. "Residential Electricity Demand in Mexico: A Model Distinguishing Access from Consumption." *Land Economics* 60(3): 268–277.

Besley, T., and R. Kanbur. 1988. "Food Subsidies and Poverty Alleviation." *The Economic Journal* 98(September): 701–719.

Bowland, Brad. J. and John C. Beghin. 1998. "Robust Estimates of Value of a Statistical Life For Developing Economies: An Application to Pollution and Mortality in Santiago." Beghin, North Carolina State University. February, mimeographed.

Braverman, Avi, Jeffrey Hammer and Choong Yong Ahn. 1987. "Multimarket Analysis of Agricultural Pricing in Korea." In Newbery, D. and Nicholas Stern, eds.

Brooks, Nancy, and Rajiv Sethi. 1997. "The Distribution of Pollution: Community Characteristics and Exposure to Air Toxics." *Journal of Environmental Economics and Management* 32: 233–250.

Buchanan, James. M. and Gordon Tullock. 1975. "Polluters' Profits and Political Response: Direct Controls Versus Taxes." *American Economic Review* 65(1): 139–147.

Christainsen, G.B., and T.H. Tietenberg. 1985. "Distributional and Macroeconomic Aspects of Environmental Policy." In A. V. Kneese and J. L. Sweeney, eds. *Handbook of Natural Resources and Energy Economics,* Vol. I. Amsterdam: Elsevier Science Publishers, B.V.

Christiansen, Vidar, and Eilev S. Jansen. 1978. "Implicit Social Preferences in the Norwegian System of Indirect Taxation." *Journal of Public Economics* 10: 217–245.

Cline, William R. 1992. *The Economics of Global Warming.* Washington D.C.: Institute for International Economics.

Eskeland, Gunnar S. 1994. "A Presumptive Pigovian Tax on Gasoline: Complementing Regulation to Mimic and Emissions Fee." *The World Bank Research Observer* 8(3): 373–394.

Eskeland, G.S. 1996. "Environmental Protection and Optimal Taxation: A Delegation Result." Development Research Group, World Bank, mimeographed.

Eskeland, Gunnar S. and S. Devarajan. 1996. *Taxing Bads by Taxing Goods: Pollution Control with Presumptive Charges.* Washington D.C.: World Bank.

Eskeland, Gunnar S. and Tarhan Feyzioglu. 1997. "Rationing Can Backfire: The " Day without a Car" in Mexico City." *The World Bank Economic Review* 11(3): 383–408.

Eskeland, Gunnar S. and Emmanuel Jimenez. 1992. "Policy Instruments for Pollution Control in Developing Countries." *The World Bank Research Observer* 7(2): 145–169.

Eskeland, Gunnar S., Emmanuel Jimenez, and Lili Liu. 1998. "Prices that clear the air: Energy Use and Air Pollution in Chile and Indonesia." *Energy Journal* 19(3): 85-106.

Feldstein, M.S. 1972. "Distributional Equity and the Optimal Structure of Public Prices." *American Economic Review* 62(1): 32–36.

Freeman, A. Myrick III. 1972. "Distribution of Environmental Quality." In Kneese, A.V. and B.T. Bower, eds. *Environmental Quality Analysis.* Baltimore and London: Johns Hopkins Press.

Goulder, Larry. 1995. "Environmental Taxation and the Double Dividend: A Reader's Guide." *International Tax and Public Finance* 2(2): 157–83.

Grossman, Gene M. and Alan B. Krueger. 1995. "Economic Growth and the Environment." *Quarterly Journal of Economics* CX(2): 353–377.

Harrison, David Jr. 1977. "Controlling Automotive Emissions: How to Save More Than $1 Billion Per Year and Help the Poor Too." *Public Policy* 25(4): 527–553.

Harrison, David Jr. and Daniel L. Rubinfeld. 1978. "The Distribution of Benefits from Improvements in Urban Air Quality." *Journal of Environmental Economics and Management* 5: 313–332.

Heady, Christopher, and Pradeep Mitra. 1987. "Optimal Taxation and Shadow Pricing in a Developing Economy. "In David Newbery and Nicholas Stern, eds. *The Theory of Taxation for Developing Countries.* Oxford University Press.

Hughes, Gordon. 1987. "The Incidence of Fuel Taxes: A Comparative Study of Three Countries." In D. Newbery and N. Stern, editors.

Hylland, Aanund, and Richard Zeckhauser. 1979. "Distributional Objectives Should Affect Taxes But Not Program Choice or Design." *Scandinavian Journal of Economics* 81(2): 264–284.

Johnson, F. Reed. 1980. "Income Distributional Effects of Air Pollution Abatement: A General Equilibrium Approach." *Atlantic Economic Journal* 8: 10–21.

Jorgenson, Dale W., and Peter. J. Wilcoxen.. 1990. "Environmental Regulation and U.S. Economic Growth." *Rand Journal of Economics* 21(2): 314–40.

Krupnick, Alan J., Margaret A. Walls, and H. Carter Hood. 1993. "The Distributional and Environmental Implications of an Increase in the Federal Gasoline Tax." Discussion Paper ENR93-24. Resources for the Future, Washington, D.C.

Lewis, G.W., and D.T.Ulph. 1988. "Poverty, Inequality and Welfare." *The Economic Journal* 98: 117–131.

Low, Patrick. 1992. "Trade Measures and Environmental Quality: The Implications for Mexico's Exports." In Patrick Low, ed., *International Trade and the Environment.* Discussion Paper No. 159. Washington, D.C.: World Bank.

Lluch, Constantion, and Alan Powell. 1975. "International Comparisons of Expenditure Patterns." *European Economic Review* 6(3): 275–303.

Maital, Shlomo. 1973. "Public Goods and Income Distribution: Some Further Results." *Econometrica* 41(3): 561–568.

McGuire, Martin C., and Henry Aaron. 1969. "Efficiency and Equity in the Optimal Supply of a Public Good." *Review of Economics and Statistics* 51: 31–39.

Mink, Stephen D. 1993. *Poverty, Population, and the Environment.* World Bank Discussion Paper No. 189. Washington, D.C.: World Bank.

Newbery, David, and Nicholas Stern. 1987. *The Theory of Taxation for Developing Countries.* Oxford University Press.

OECD. 1975. *The Polluter Pays Principle.* Paris: Organization for Economic Cooperation and Development.

Ostro, Bart. 1994. "The Health Effects of Air Pollution: A Methodology and an Application to Jakarta." Policy Research Working Paper No. 1301. Development Research Group, World Bank , Washington, D.C.

Pearce, David W. 1980. "The Social Incidence of Environmental Cost and Benefits." *Progress in Resource Management and Environmental Planning* (2): 63–87.

Peskin, Henry M. 1978. "Environmental Policy and the Distribution of Benefits and Costs." In Paul R. Portney, editor. *Current Issues in U.S. Environmental Policy.* Baltimore and London: Johns Hopkins University Press.

Pitt, Mark M. 1985. "Equity, externalities and energy subsidies: The Case of Kerosene in Indonesia." *Journal of Development Economics* 17: 201–217.

Ravallion, Martin. 1994 . "Measuring Social Welfare With and Without Poverty Lines." *American Economic Review* 84(2): 359–364.

Ravallion, M., and D. van de Walle. 1991. "Urban-Rural Cost of Living Differentials in Developing Economy." *Journal of Urban Economics* 29: 113–127.

Rose, Adam, Brandt Stevens and Gregg Davis. 1988. *Important Dimensions of Natural Resource Policy*. Johns Hopkins Press.

Samuelson, Paul A. 1954. "The Pure Theory of Public Expenditure." *Review of Economics and Statistics* 36: 387–9.

Sandmo, A. 1975. "Optimal Taxation in the Presence of Externalities." *Swedish Journal of Economics* 77: 86–98

Selden, Thomas M., and D. Song. 1994 . "Environmental Quality and Development: Is there a Kuznets Curve for a Pollution Emissions?" *Journal of Environmental Economics and Management* 27: 147–162.

Sexton, Ken, Henry Gong Jr., John C. Bailar III, Jean G. Ford, Diane R. Gold, William E. Lambert and Mark J. Utell. 1993. "Air Pollution Health Risks: Do Class and Race Matter?" *Toxicology and Industrial Health* 9(5): 843–878.

Smith, V. Kerry, and Ju-Chin Huang. 1995 . "Can Markets Value Air Quality? A Meta-Analysis of Hedonic Property Value Models." *Journal of Political Economy* 103(1): 209–227.

Stephan, G. R., R. van Niewkoop and T. Wiedmer. 1992 . "Social Incidence and Economic Costs of Carbon Limits: A Computable General Equilibrium Analysis for Switzerland." *Environmental and Resource Economics* 2: 569–91.

U.S. Environmental Protection Agency. 1986. "Compilation of Air Pollutant Emission Factors." *Stationary Point and Area Sources,* Supplement A, October, Volume 1, Research Triangle Park, N.C.

Varian, Hal R. 1984. *Microeconomic Analysis.* New York: W.W. Norton & Company, 2nd edition.

Viscusi, W. K., W. A. Magat, A. Carlin and M. Dreyfus. 1994 . "Environmentally Responsible Energy Pricing." *Energy Journal* 15(2): 23–42.

Weaver, C.S., and M.J. Reale. 1994 . "Development of Composite Fuel Specific Emission factors for Air Pollutants in Java, Indonesia, and Santiago, Chile." Engine, Fuel and Emissions Engineering in Sacramento, California. Mimeo.

Wernstedt, K. 1995. "Regional Environmental Policy and the Distribution of Economic Impacts Among Rural Households." *Journal of Environment and Planning* 27: 645–662

Whalley, John, and R. Wigle. 1991 . "Cutting CO_2 Emissions: The Effects of Alternative Policy Approaches." *Energy Journal* 22(1): 109–124.

World Bank. 1992. *World Development Report.* Washington, D.C.

World Bank. 1994. "The Net Benefits of an Air Pollution Control Scenario for Santiago." In World Bank: "Chile: Managing Environmental Problems: Economic Analysis of Selected Issues." Report No. 13061-CH. Latin America and the Caribbean Region, Washington, D.C.

World Commission on the Environment. 1987. *Our Common Future*. New York: United Nations.

Annex Table 1: Expenditure Shares, Transport and Energy

	Private transport	Public transport	Electricity	Coal	Firewood	Kerosene	Gas
			A. Java				
Quintile 1	0.002	0.012	0.007	0.0004	0.065	0.036	0.000
Quintile 2	0.004	0.013	0.009	0.0007	0.049	0.030	0.000
Quintile 3	0.007	0.017	0.012	0.0009	0.036	0.028	0.000
Quintile 4	0.015	0.025	0.016	0.0009	0.024	0.028	0.000
Quintile 5	0.043	0.038	0.022	0.0004	0.009	0.022	0.002
			B. Rest of Java				
Quintile 1*	0.002	0.012	0.007	0.0003	0.065	0.036	0.000
Quintile 2	0.004	0.013	0.009	0.0007	0.050	0.030	0.000
Quintile 3	0.008	0.015	0.012	0.0009	0.037	0.028	0.000
Quintile 4	0.017	0.020	0.015	0.001	0.026	0.026	0.000
Quintile 5	0.048	0.026	0.018	0.0006	0.013	0.021	0.001
			C. Jakarta				
Quintile 1*	0.000	0.024	0.019	0.000	0.0000	0.106	0.000
Quintile 2	0.000	0.058	0.028	0.000	0.0000	0.050	0.000
Quintile 3	0.0003	0.068	0.025	0.0001	0.0002	0.046	0.0005
Quintile 4	0.003	0.076	0.025	0.0002	0.0001	0.043	0.0001
Quintile 5	0.031	0.062	0.031	0.000	0.0001	0.023	0.004

* the partition is, for all three area definitions, in terms of Java quintiles. The per capita income ranges are as follows: (rupiah/month)

Quintile 1	[9620	60153]	Mean: 43966
Quintile 2	[60163	84746]	72494
Quintile 3	[84752	114395]	98578
Quintile 4	[114438	173507]	139313
Quintile 5	[173582	5436245]	323098

Annex Table 2: Expenditure Shares, A 9 Good System

	Food	Alcohol and tobacco	Public transport	Private transport	Energy	Housing	Clothing	Services	Others
				A. Java					
Quintile 1	.634	.056	.012	.002	.110	.078	.051	.032	.052
Quintile 2	.630	.059	.013	.004	.091	.069	.056	.042	.058
Quintile 3	.619	.062	.017	.007	.080	.068	.059	.050	.061
Quintile 4	.585	.064	.025	.015	.071	.076	.059	.060	.069
Quintile 5	.488	.055	.038	.043	.060	.110	.056	.103	.076
				B. Rest of Java					
Quintile 1*	.634	.056	.012	.002	.109	.077	.051	.032	.052
Quintile 2	.630	.059	.013	.004	.091	.068	.056	.042	.058
Quintile 3	.621	.061	.015	.008	.080	.066	.059	.050	.061
Quintile 4	.593	.062	.020	.017	.070	.069	.060	.061	.072
Quintile 5	.518	.055	.026	.048	.057	.084	.057	.100	.088
				C. Jakarta					
Quintile 1*	.430	.067	.024	.000	.125	.239	.047	.019	.050
Quintile 2	.536	.106	.058	.000	.090	.234	.038	.041	.050
Quintile 3	.490	.099	.068	.000	.083	.184	.048	.045	.038
Quintile 4	.470	.088	.076	.003	.079	.158	.048	.050	.041
Quintile 5	.422	.054	.062	.031	.065	.166	.052	.108	.052

* The same definition as in Table 1 applies.

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